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14. ABSTRACT The project investigated novel sources of terrain information, often termed volunteered geographic information. Such information is transforming the geospatial world, providing new sources that are in many cases more timely and accurate than traditional, authoritative sources. Specific areas of focus during the project included assurance of data quality, impacts on traditional production methods, new approaches to terrain-type classification, and the relative importance of space, defined by measured coordinates, and place, defined by commonly used names. The					
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a. REPORT UU	b. ABSTRACT UU	c. THIS PAGE UU			19b. TELEPHONE NUMBER 805-893-8049

## Report Title

Final Report: User-Generated Terrain Information

### ABSTRACT

The project investigated novel sources of terrain information, often termed volunteered geographic information. Such information is transforming the geospatial world, providing new sources that are in many cases more timely and accurate than traditional, authoritative sources. Specific areas of focus during the project included assurance of data quality, impacts on traditional production methods, new approaches to terrain-type classification, and the relative importance of space, defined by measured coordinates, and place, defined by commonly used names. The project resulted in several papers in refereed journals, a major edited book, presentations at many conferences, and a series of workshops at conferences. Research interest in this area is growing, and the general public is becoming substantially more engaged with both the use and production of terrain information.

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**Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:**

**(a) Papers published in peer-reviewed journals (N/A for none)**

<u>Received</u>	<u>Paper</u>
02/16/2011	2.00 Michael F. Goodchild. The quality of geospatial context, Lecture Notes in Computer Science, (01 2009): . doi:
02/16/2011	1.00 Michael F. Goodchild, J. Alan Glennon. Crowdsourcing geographic information for disaster response: a research frontier, International Journal of Digital Earth, (09 2010): . doi:
04/23/2012	6.00 Darren Hardy, James Frew, Michael F. Goodchild. Volunteered geographic information production as a spatial process, International Journal of Geographical Information Science, (01 2012): 0. doi: 10.1080/13658816.2011.629618
04/26/2013	10.00 Linna Li, Michael F. Goodchild, Bo Xu. Spatial, temporal, and socioeconomic patterns in the use of Twitter and Flickr, Cartography and Geographic Information Science, (03 2013): 0. doi: 10.1080/15230406.2013.777139
04/26/2013	12.00 Michael F. Goodchild. The future of Digital Earth, Annals of GIS, (06 2012): 0. doi: 10.1080/19475683.2012.668561
08/15/2011	4.00 Linna Li, Michael F. Goodchild. The role of social networks in emergency management: a research agenda., International Journal of Information Systems for Crisis Response and Management, (10 2010): 49. doi:
08/22/2012	8.00 Michael F. Goodchild, Linna Li. Assuring the quality of volunteered geographic information, Spatial Statistics, (05 2012): 0. doi: 10.1016/j.spasta.2012.03.002
08/22/2012	7.00 Sarah Elwood, Michael Goodchild, Daniel Sui. Researching volunteered geographic information: spatial data, geographic research, and new social practice, Annals of the Association of American Geographers, (08 2012): 571. doi:
08/22/2012	9.00 Daniel Sui, Michael Goodchild. The convergence of GIS and social media: challenges for GIScience, International Journal of Geographical Information Science, (11 2011): 1737. doi:
<b>TOTAL:</b>	<b>9</b>

**Number of Papers published in peer-reviewed journals:**

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**(b) Papers published in non-peer-reviewed journals (N/A for none)**

<u>Received</u>	<u>Paper</u>
04/26/2013	13.00 Michael F. Goodchild, Huadong Guo, Alessandro Annoni, Ling Bian, Kees de Bie, Frederick Campbell, Max Craglia, Manfred Ehlers, John van Genderen, Davina Jackson, Anthony J. Lewis, Martino Pesaresi, Gábor Remetey-Fülöpp, Richard Simpson, Andrew Skidmore, Changlin Wang, Peter Woodgate. Next-generation Digital Earth, Proceedings of the National Academy of Sciences, (07 2012): 11088. doi:
<b>TOTAL:</b>	<b>1</b>

**Number of Papers published in non peer-reviewed journals:**

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**(c) Presentations**

"Old Debates, New Opportunities". Progress in Human Geography Plenary, Annual Meeting, Association of American Geographers, Los Angeles, April 2013.

"Emerging Trends: Communities". Keynote, EUROGI imaGIne Conference, Dublin, March 2013.

"Exploring Digital Earth". Keynote, 47th Annual Alaska Surveying and Mapping Conference, Anchorage, February 2013.

"Visualizing Geospatial Uncertainty". Distinguished Lecture, SCI Institute, University of Utah, January 2013.

"Geographic Intelligence". Keynote, SpaceTimeLab Launch Event, University College, London, October 2012.

"Exploring Digital Earth". Keynote, GIS-Pro 2012, Portland, OR, October.

"The Future of Digital Earth". Keynote, GeoInformatics 2012, Chinese University of Hong Kong, June.

"Reflections and Visions". Keynote, Global Geospatial Conference, Québec, May 2012.

"Communicating Spatial Uncertainty". Annual Meeting, Association of American Geographers, New York, February 2012.

"Where are We? The Spatial Sciences in 2011". Keynote, Surveying and Spatial Sciences Conference, Wellington, NZ, November 2011.

"Geographical Intelligence". Keynote, GeoMundus Conference, Münster, Germany, October 2011.

"Digital Earth: Inventory and Prospect". Keynote, Hengstberger Symposium "Towards Digital Earth: 3D Spatial Infrastructures". University of Heidelberg, September 2011.

"Geographic Intelligence". Keynote, European Colloquium on Quantitative and Theoretical Geography, Harokopio University, Athens, September 2011.

"Geographic Intelligence". Keynote, GeoInformatics 2011, Shanghai, June.

"It's about Time: The Temporal Dimension in VGI". Keynote, Esri Redlands Week, February 2011.

"Researching the Geocrowd". Opening Keynote, Third Spatial Socio-Cultural Knowledge Workshop, Defence Academy, Shrivenham, UK, June 2010.

**Number of Presentations:** 16.00

**Non Peer-Reviewed Conference Proceeding publications (other than abstracts):**

<u>Received</u>	<u>Paper</u>
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**TOTAL:**

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**Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):**

**Peer-Reviewed Conference Proceeding publications (other than abstracts):**

<u>Received</u>	<u>Paper</u>
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**TOTAL:**

**Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):**

### (d) Manuscripts

<u>Received</u>	<u>Paper</u>
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08/15/2011	5.00	Sarah Elwood, Michael F. Goodchild, Daniel Z. Sui. Researching volunteered geographic information: spatial data, geographic research, and new social practice, <i>Annals of the Association of American Geographers</i> (08 2011)
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**TOTAL: 1**

**Number of Manuscripts:**

## Books

Received      Paper

04/26/2013    11.00 D.Z. Sui, S. Elwood, M.F. Goodchild. Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice, New York: Springer, (12 2012)

**TOTAL:            1**

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### **Patents Submitted**

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### **Patents Awarded**

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### **Awards**

"Reflections on Geographic Information Science: special issue in honor of Michael Goodchild". Guest editors Nina Siu-Ngan Lam and Karen Kemp. International Journal of Geographical Information Science 26 (11–12), 2012.

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CODATA Prize, 2012 (given by the Committee on Data for Science and Technology of the International Council for Science)

Peter A. Burrough Medal, International Spatial Accuracy Research Association, 2012

Fellow, University Consortium for Geographic Information Science, 2010–

Corresponding Fellow, the British Academy, 2010–

Foreign Member, the Royal Society, 2010–

UCGIS Research Award, 2010, University Consortium for Geographic Information Science

Honorary Professor, Capital Normal University, Beijing, 2009–

Honorary Professor, Chinese University of Mining and Technology, Xuzhou, 2009–

Digital Earth Prize for Scientific Contributions, International Society for Digital Earth, 2009

Honorary Director, Academic Committee, Jiangsu Key Laboratory of Resources and Environmental Information Engineering, Chinese University of Mining and Technology, Xuzhou, 2009–

Visiting Professor, Sichuan University, Chengdu, 2008–

Honorary Professor, Tongji University, Shanghai, 2008–

Sigma Xi Distinguished Lecturer, 2009–2011

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### **Graduate Students**

<u>NAME</u>	<u>PERCENT SUPPORTED</u>	Discipline
Daren Hardy	0.63	
Ben Adams	0.49	
	0.00	
<b>FTE Equivalent:</b>	<b>1.12</b>	
<b>Total Number:</b>	<b>2</b>	

#### Names of Post Doctorates

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
Linna Li	1.00
<b>FTE Equivalent:</b>	<b>1.00</b>
<b>Total Number:</b>	<b>1</b>

#### Names of Faculty Supported

<u>NAME</u>	<u>PERCENT SUPPORTED</u>	National Academy Member
Michael Goodchild	0.11	Yes
Martin Raubal	0.00	
Krzysztof Janowicz	0.00	
<b>FTE Equivalent:</b>	<b>0.11</b>	
<b>Total Number:</b>	<b>3</b>	

#### Names of Under Graduate students supported

<u>NAME</u>	<u>PERCENT SUPPORTED</u>	Discipline
Douglas Carreiro	0.29	Geography
Shaunt Der-Gregorian	0.29	Geography
Stephanie Truitt	0.00	Geography
David Avon	0.00	Geography
Tiffany Armstrong	0.00	Geography
Lisa Berry	0.00	Geography
Alex Hammer-Barulich	0.00	Geography
<b>FTE Equivalent:</b>	<b>0.58</b>	
<b>Total Number:</b>	<b>7</b>	

#### Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: ..... 7.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:..... 7.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:..... 2.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):..... 7.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense ..... 2.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:..... 1.00

**Names of Personnel receiving masters degrees**

<u>NAME</u>
<b>Total Number:</b>

**Names of personnel receiving PHDs**

<u>NAME</u>
Ben Adams
<b>Total Number:</b> 1

**Names of other research staff**

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
<b>FTE Equivalent:</b>	
<b>Total Number:</b>	

**Sub Contractors (DD882)**

**Inventions (DD882)**

**Scientific Progress**

This project was motivated by the rapid expansion in the number and size of websites devoted to gathering geographic information supplied on a voluntary basis by users. This phenomenon of volunteered geographic information (VGI) is part of a more general trend of user-generated content facilitated by a suite of technologies loosely known as Web 2.0. VGI presents significant new challenges for GIScience research, where existing theory and practices are geared almost exclusively toward more conventional forms of spatial data. Yet to date there have been no rigorous studies investigating the scientific and societal questions raised by this phenomenon. Little is known about why people contribute information, the accuracy or quality of what they produce, appropriate methods for synthesizing or analyzing these data, how the so-called "digital divide" may operate to inhibit some people from contributing VGI, or how this phenomenon may impact privacy and confidentiality.

Two major themes were pursued at UCSB: the quality of VGI, and the role of community engagement in redefining geographic information. In addition we conducted extensive outreach activities, striving to ensure that the project had as much external impact as possible. Besides major publications, we also organized several workshops at conferences, and gave several speeches at conferences around the world.

On the data quality topic we explored the notion that three approaches are possible to quality assurance for VGI. First, the "wisdom of the crowd" suggests that quality can be assured or improved by facilitating review of purported facts by as many people as possible. This approach also proposes that the number of people independently proposing the same fact can be used as an indicator of quality. Examining the issues involved in this approach in practice, we quickly discovered that the "wisdom of the crowd" is problematic for many VGI projects. Many geographic facts are obscure, leading to little interest on the part of others in ensuring that they are correct. Many VGI sites are motivated primarily by the acquisition of data rather than by its use. Finally, we found that it is quite challenging to determine whether two assertions are actually of the same fact, given the flexibility both in describing location and in describing what is present at that location. For example, "wildfire in Santa Barbara" may or may not be asserting the same fact as "house burning in Montecito".

The second potential approach to quality assurance is based on the notion of trust, and the development of social hierarchies of moderation and approval. This approach is used by Wikipedia, Google's MapMaker, OpenStreetMap, and many other projects. In effect, it mirrors in the volunteer world the kind of administrative hierarchies found in government agencies, and employed in traditional production of geographic information. The major disadvantage of the approach is that it requires human action, and is consequently too slow and labor-intensive to be an ideal solution for VGI, given the advantages of VGI in time-critical situations.

We devoted most of our time to the third approach, which is based on establishing a set of rules through which one can automatically determine whether a purported fact is true, or likely to be true. This approach is already in use in some corporations that would otherwise be flooded by assertions, but the rule sets are typically domain-specific and ad hoc. The approach can be generalized to the question: How can one tell if a purported geographic fact, or set of facts, is true? We explored this issue by identifying candidates for general rules and domain-specific rules, exploring the accumulated body of geographic knowledge for such rules, and developing appropriate algorithms. We found a large literature on imagined geographic worlds, and found examples where such imagined worlds were remarkably consistent with known rules of geographic syntax.

On the community engagement topic, we focused on identifying the ways in which VGI, and neogeography more broadly, were redefining the nature of geographic information and the practices of geographic information production. First, new types of geographic information are emerging, especially those that are time-dependent and socially relevant. Second, it is possible to identify two clearly distinct options in VGI development: towards a global hegemony, represented by the schema.org project of Microsoft, Google, and Yahoo!, or towards a new local, cultural, and linguistic sensitivity. Third, VGI is leading to a rediscovery of place, and to the exploitation of place-related concepts, away from the strongly spatial tradition of GIS.

On the topic of place, we explored the potential of Flickr, Twitter, and other social media to support the mapping and characterization of place. We formulated a notion of a platial GIS, and examined its functionality and its relationship to traditional spatial GIS.

VGI research continues to advance, with an expanded research agenda, due in part to the influence and timely nature of our project; and ripples can be seen in related projects in other disciplines, and in increased interest among geographers in related topics such as Big Data and CyberGIS.

## **Technology Transfer**